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CASE STUDY ON THE OPERATION OF SMART REFRIGERATED WAREHOUSE IN BUSAN

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Abstract. *Busan is the largest port of South Korea and its logistics industry, which is larger than that of any other city, plays an important role in the local economy. Although the city has made various efforts to boost the port's logistics industry, it needs to develop diverse policies and technologies linked to the 4th industrial revolution. Accordingly, this study explores operating a smart refrigerated warehouse to ensure more and better use of the Busan New Port in relation to the 4th industrial revolution. It suggests operational direction of the smart refrigerated warehouse in Busan by presenting technologies applied to it and cases.*
Keywords: Refrigerated warehouse, Smart system, Operation, Logistics system

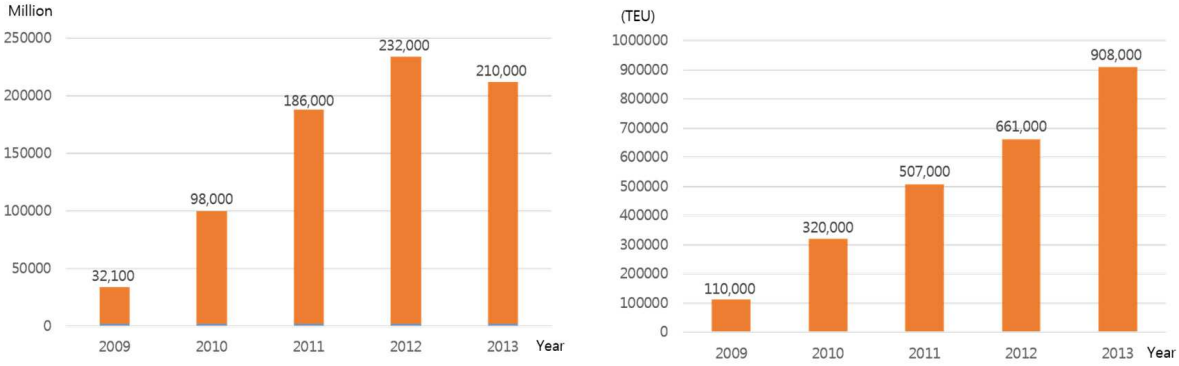
1. **Introduction.** To develop the logistics industry further, it is important to incorporate logistics management and engineering information communications technologies (ICT) logistics systems [1,2]. The Korean government has designated the logistics industry as one of seven promising service businesses and tried to promote it as a growth engine for the future. However, it has yet to establish an organized method for promoting smart logistics for the cold warehouse industry. An innovative logistics system would go beyond a simple business model to include convergence with IT, hardware and software related to logistics [3]. The existing cold warehouses in the Busan port have been operating mainly as storage and, thus, have lost their competitiveness and suffered from financial difficulties. They have been unsuccessful in providing tailored logistics services to their customers or building a cooperative global business network. Related studies on cold warehouses evaluated their efficiency with a focus on storage performance and proposed technological methods to improve operating practices [4,5]. Smart storage technologies can online detect and monitor the changes of quality parameters and storage environment of fresh foods during storage, so that operators can make timely adjustments to reduce the loss. Their results provided limited direction for moving toward the use of a smart refrigerated warehouse. This suggested concept on smart refrigerated warehouse can be proposed by new approaches to analyze the performance of smart refrigerated warehouse. A need exists for more ways to promote the Busan New Port, so the goal of this study is to propose technologies to develop a smart refrigerated warehouse at the Busan New Port as well as an operation method for use in promoting the port. Chapter 2 of the study describes the current operation of the Busan New Port. Chapters 3 and 4 explain the technologies needed to operate a smart refrigerated warehouse and its operation case, respectively. Finally, Chapter 5 reaches a conclusion.

2. **Current Logistics Industry of Busan.** Supporting the hinterland of the Busan New Port requires establishment of an international port logistics cluster and logistics

TABLE 1. New port hinterland development plan

Item	North "con" hinterland	Eungdong complex	West "con" hinterland	South "con" hinterland
Total area	2,226,000 m^2	3,579,000 m^2	2,168,000 m^2	1,422,000 m^2
Logistics area	1,153,000 m^2	2,165,000 m^2	1,343,000 m^2	951,000 m^2
Project period	2001∼2020	2006∼2015	2012∼2020	2012∼2017

Source: Busan Port Authority (2017)



Source: Busan Port Authority (2013)

FIGURE 1. Operation performance of the Busan New Port logistics

complex, which will add significant value, through specialization and meeting customers' needs by providing timely service to the hinterland. The new port hinterland development plan is shown by Table 1.

As Figure 1 shows, the logistics industry of Busan experienced worsening internal and external business conditions, as well as poor operations performance, and subsequently lost its global competitiveness. Enterprises located at the Busan New Port have created insufficient added value and trade volume for several reasons. First, they do not have a statistical system that can quantitatively demonstrate their added-value creating activities. Second, most of them simply store goods and load/unload them for storage, which is quite different from their business proposal, which includes various value creating activities. Third, some of them have recently made great efforts in added-value creating business activities and have experienced a series of trial and error in accomplishing the activities (reassembly of cars and repackaging, etc.). The added-value activities in the port hinterland do not develop by themselves. Rather, they are outcomes that the enterprises must create. Fourth, most of them have a weak overseas sales network for attracting added-value activities and do not have direct foreign involvement in their business management. They have focused on the existing business model of domestic containers and this negatively affected their already insufficient added-value creating activities. Fifth, most of them failed to bring to realization the business model they proposed when they were selected, creating unsatisfactory trade volume. Sixth, the trade volume of the enterprises operating at the port as of 2013 was about 600,000 TEU, which accounted for 60% of the planned volume (1 million TEU). The business proposal submitted by the enterprises explained that their planned transshipment traffic with high added value in 2013 was approximately 300,000 TEU. However, the actual traffic was about 50,000 TEU or 16% of the original plan. There is fierce competition caused by weak foundations in the creation of new trade volume. First, most of the enterprises at the Busan New Port put more effort into transporting the existing local containers than bringing new overseas trade because they faced challenges in building a specialized new business model. This

triggered price competition among them as they struggled to transport the existing containers. Second, the price competition among them led to decreased sales even though the year-on-year trade volume was similar. Third, the pace of supplying the hinterland should have been controlled since oversupply caused them to engage in storage fee dumping. The enterprises at the Busan New Port are struggling with limited new trade (limited logistics service) and fierce competition, and because of this, they are concerned about worsening performance and competitiveness in the port logistics industry that has been caused by decreased added value and less trade.

3. **Operation Method of the Smart Refrigerated Warehouse.** Tailored logistics services that meet customers' differing needs are not adequately provided and a cooperative global business network has not been completely established. That is why diverse approaches are required to promote the Busan New Port and technologies to operate the smart refrigerated warehouse in the Busan New Port should be developed and applied to achieve the goal [6,7]. The requirements of Busan city to build the smart refrigerated warehouse are as follows. First, based on the definition of the smart refrigerated warehouse, the business approach study has been only an exploratory discussion as it failed to deal with the issues in detail. Hence, a convergence study that applies smart technologies and engineering approaches should be performed. Second, the concept of the smart refrigerated warehouse should be added to the scope of existing studies on global logistics to establish the logistics business model for the Busan New Port hinterland that applies business network management techniques. Third, strategies should be set up to build and operate the smart refrigerated warehouse. The characteristics of the smart refrigerated warehouse include providing an end-to-end solution with the goal of integration; horizontal system integration of the shipper, refrigerated warehouse (inbound logistics, outbound logistics, marketing), and carrier based on ICT; vertical system integration of the operation processes of the logistics warehouse based on ICT; and application of the related technologies to the logistics company and operation. Smart storage technologies can online detect and monitor the changes of quality parameters and storage environment of fresh foods during storage, so that operators can make timely adjustments to reduce the loss.

4. **Technologies to Build the Smart Refrigerated Warehouse.**

4.1. **Operating technologies.** We have suggested the new smart refrigerated warehouse model. Figure 2 shows the concept map needed to build the smart refrigerated warehouse. Cargoes with their information identified are processed into the smart refrigerated warehouse on the automatic conveyer belt and moved to a vertical lift that leads to a path to a designated automatic warehouse. The moved cargoes enter the automatic warehouse with a rail guided vehicle (RGV) and are stored on the designated rack by a stacker crane.

– **MPS (Multi-Purpose System) using IoT.** MPS stands for multi-purpose system using the IC tag technology that automatically notifies workers of the product and quantity when they check inbound goods, outbound goods, and their inventory, improving work efficiency and accuracy. That is, the existing warehouse management system (WMS) uses the IC tags such as Bluetooth or RFID technology to realize the IoT (Internet of things) environment. The WMS shows inventory location, inbound location, inbound time, and days of storage as well as providing real time analysis on asset changes. It enables efficient management of all work performed at the warehouse (inbound, outbound, storage, picking outbound and inventory check, etc.), saving inventory management cost as well as enhancing physical inventory accuracy using the automatic conveyor system applied by the MPS as Figure 3. Additionally, it helps provide better service for the customers and

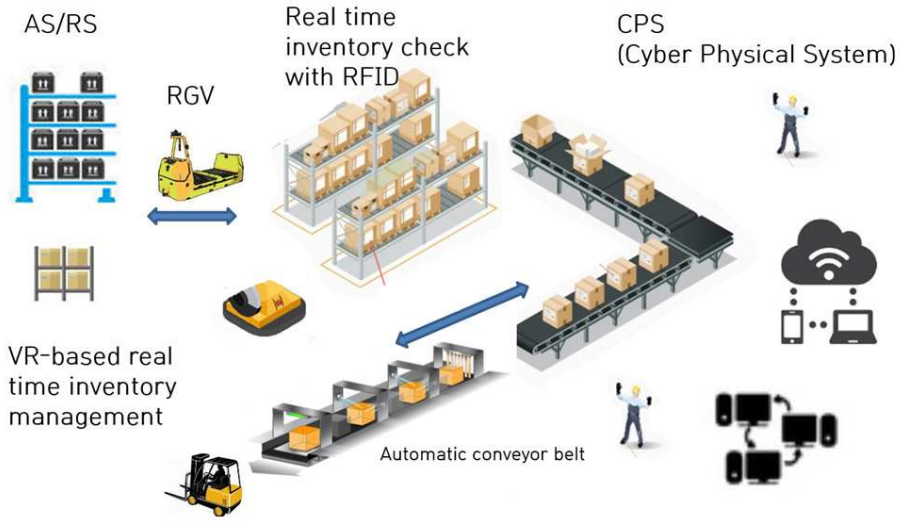


FIGURE 2. Concept map of the smart refrigerated warehouse

FIGURE 3. Automatic conveyor system

maintains the inventory at an appropriate level by efficiently using management resources such as warehouse area, workers, and unloading equipment with minimum cost.

– **Cargo transportation using the RGV.** The rail guided vehicle (RGV) is a vehicle that transports the pallets sent by the vertical lift from the inbound/outbound area on the first floor to each AS/RS. The RGV that is closest to the cargoes placed on each vertical lift moves to transport the pallets to the warehouse. Figure 4 shows operation of the RGV to carry out the pallets into AS/RS.

– **Inbound to and outbound from the AS/RS.** The inbound cargoes from the inbound/outbound area are transported to the AS/RS (automated storage and retrieval system) by the vertical lift and the transported cargoes are stored on the designated rack at the loading/unloading area by the stacker crane in the path as Figure 5.

– **Data security using ISMS.** It is critical to maintain information security in the stage that collects and manages information by using the RFID IC tag and sensor to prevent wrong information from coming through a wrong route or to prevent important information from leaking. Therefore, a system should be established that wirelessly transmits data to a secured server using a protocol that encrypts sensors. A special algorithm should be created that keeps unauthorized personnel from accessing the server. Additionally,

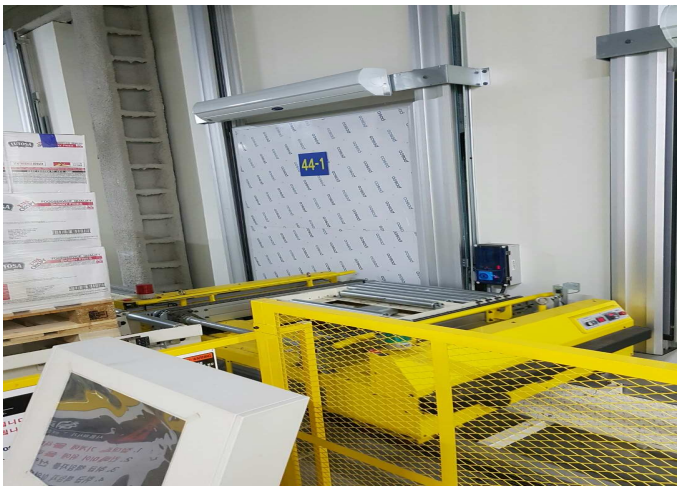


FIGURE 4. RGV operation

FIGURE 5. AS/RS operation

certification of the ISMS (information security management system) that is established to provide technological and physical protection for a safe information communication network should be obtained.

– **CPS-based real-time monitoring of the refrigerated warehouse.** Refrigerated warehouses of large supermarkets have a system that shows information of their products stored in the warehouse on a screen through a 3D technology. This enables the warehouse managers to more efficiently monitor the inventory by expiration dates, picking status, inventory by days of storage and frequency of product release by viewing a 3D screen. It is established through interconnection of a perspective-oriented method and an object-oriented method that are cyber-physical systems (CPS)-based virtual simulation modeling technology.

4.2. **Operation case of the smart refrigerated warehouse.** A smart refrigerated warehouse (a company) in Busan has an automated cold storage (AS/RS) and refrigerated warehouse. It has 17 forklifts in total, 12 on the first floor, two on the second floor and three on the third floor. Cargoes are transported from the inbound/outbound area on the first floor to the automated cold storage by vertical lifts on the conveyor belt. The company has eight vertical lifts with speeds of 90 m/min. The pallets moved by the vertical lifts are transported again into the AS/RS by four RGVs and these pallets are stored on a double rack by four stacker cranes, which have driving speeds of 200 m/min

and lifting speeds of 80 m/min. The AS/RS has a total of 31,000 pallets that account for about 50% of their storage capacity and its daily workload is 2,000 to 2,500 pallets. The maximum workload per day is 2,500 pallets. Though the storage rate is 50% compared with other companies, the company has a similar result to that of other companies in terms of the operation efficiency. We have applied the concept of this study and showed the operation results of smart refrigerated warehouse located in Busan. It means that our model can be applied at other refrigerated warehouses to analyze the performance.

5. **Conclusion.** The study presented the way to establish and operate the smart refrigerated warehouse that Busan needs. Accordingly, it introduced the operation technologies for the smart refrigerated warehouse and evaluated operation efficiency of the smart refrigerated warehouse in Busan based on the technologies. This helps trace the cold cargoes in real time, check and ship the inventory easily, reduce possible damage, improve safety, save labor cost, and efficiently manage the warehouse. However, the operation performance of the smart refrigerated warehouse could not be completely evaluated because of insufficient operation data even though it is currently operating. Therefore, highly efficient operation methods for the smart refrigerated warehouse will be presented through continued evaluation of the operation system followed by identification and analysis of operational problems. An operation model for it will be suggested with establishment and analysis of the ongoing CPS.

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